INDEPENDENT ORBITER ASSESSMENT

ASSESSMENT OF THE ASCENT THRUST VECTOR CONTROL ACTUATOR SUBSYSTEM

05 FEBRUARY 1988

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
HOUSTON DIVISION

SPACE TRANSPORTATION SYSTEM ENGINEERING AND OPERATIONS SUPPORT

WORKING PAPER NO. 1.0-WP-VA88003-03

INDEPENDENT ORBITER ASSESSMENT
ASSESSMENT OF THE ASCENT THRUST VECTOR CONTROL ACTUATOR SUBSYSTEM FMEA/CIL

05 FEBRUARY 1988

This Working Paper is Submitted to NASA under
Task Order No. VA88003, Contract NAS 9-17650

PREPARED BY: R.E. Wilson
R.E. Wilson
Senior Analyst
Independent Orbiter Assessment

APPROVED BY: Anthony J Marino
A.J. Marino
Section Manager-FMEA/CIL
Independent Orbiter Assessment

APPROVED BY: G.W. Knori
G.W. Knori
Technical Manager
Independent Orbiter Assessment

APPROVED BY: J.I. McPherson
J.I. McPherson
Project Manager
STSEOS

CONTENTS

List of Figures

List of Tables

Independent Orbiter Assessment
Assessment of the ATVC Actuator Subsystem FMEA/CIL

1.0 EXECUTIVE SUMMARY

The McDonnell Douglas Astronautics Company (MDAC) was selected in June 1986 to perform an Independent Orbiter Assessment (IOA) of the Failure Modes and Effects Analysis (FMEA) and Critical Items List (CIL). Direction was given by the STS Orbiter and GFE Projects Office to perform the hardware analysis using the instructions and ground rules defined in NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986.

The IOA effot fist completed and analysis of the Ascent Thrust Vector Control Actuator (ATVC) hardware, generating draft failure modes and potential critical items. To preserve independence, this analysis was accomplished without reliance upon the results contained within the NASA FMEA/CIL documentation. The IOA results were then compared to the NASA FMEA/CIL baseline with proposed Post 51-L updates included. A resolution of each discrepancy from the comparison is provided through additional analysis as required. This report documents the results of that comparison for the Orbiter ATVC hardware.

The IOA produt for the ATVC actuator analysis consisted of twenty-five failure mode "worksheets" that resulted in sixteen potential critical items being identified. Comparison was made to the NASA baseline (as of 7 December 1987) which consisted of (Note 1) twenty-one FMEAs and Thirteen CIL items. The comparison dtermined if there were any results which had been found by the IOA but were not in the NASA baseline. This comparison produced agreement on all CIL items. Based on the Pre 51-L baseline, all non-CIL FMEAs were also in agreement. Based on discussions with the NASA subsystem manager, no additional non-CIL FMEAs are anticipated for the post 51-L update. Figure 1 presents a comparison of the proposed Post 51-L NASA baseline, with the IOA recommended baseline, and any issues.

Note 1. The comparison of NASA FMEA Non-CIL item is based on the Pre 51-L baseline since all Post 51-L FMEAs have not been received as date of this report.

MAIN ENGINE (ATVC) ACTUATOR ASSESSMENT OVERVIEW

ATVC ACTUATOR ASSESSMENT SUMMARY

	ORIGINAL ASSESSMENT*			FINAL RESOLUTION**		
	IOA	NASA	ISSUES	IOA	NASA	ISSUES
FMEA	25	21	4	21	21	0
CIL	16	13	3	13	13	0

PRIMARY PISTON ASS'Y

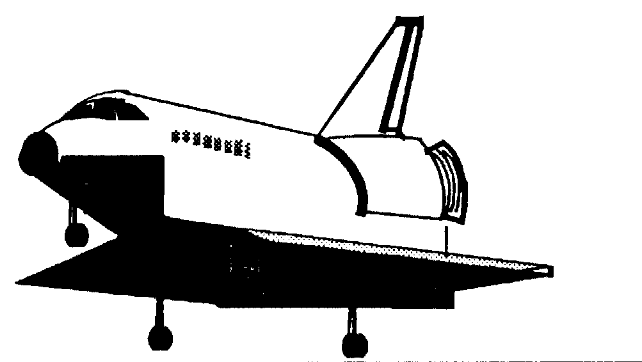
	IOA	*NASA*	*ISSUES*
FMEA	2	2	0
CIL	2	2	0

SERVOACTUATOR

	IOA	NASA	ISSUES
FMEA	3	2	1
CIL	3	2	1

HYDRAULIC VALVE MOD.

	IOA	NASA	ISSUES
FMEA	20	17	3
CIL	11	9	2



* *NASA PROPOSED BASELINE AS OF 5 MAY 1987*

** *FINAL NASA CIL ITEMS BASELINE AS OF 7 DECEMBER 1987 AND NASA NON-CIL FMEAS – PRE 51-L BASELINE*

Figure 1 - MAIN ENGINE ACTUATOR ASSESSMENT SUMMARY

2.0 INTRODUCTION

2.1 Purpose

The 51-L Challenger accident prompted the NASA to readdress safety policies, concepts, and rationale being used in the National Space Transportation System (NSTS). The NSTS Office has undertaken the task of reevaluating the FMEA/CIL for the Space Shuttle design. The MDAC is providing an independent assessment of the proposed Post 51-L Orbiter FMEA/CIL for completeness and technical accuracy.

2.2 Scope

The scope of the independent FMEA/CIL assessment activity encompasses those Shuttle Orbiter subsystems and GFE hardware identified in the Space Shuttle Independent FMEA/CIL Assessment Contractor Statement of Work. Each subsystem analysis addresses hardware, functions, internal and external interfaces, and operational requirements for all mission phases.

2.3 Analysis Approach

The independent analysis approach is a top-down analysis utilizing as-built drawings to breakdown the respective subsystem into components and low-level hardware items. Each hardware item is evaluated for failure mode, effects, and criticality. These data are documented in the respective subsystem analysis report, and are used to assess the proposed Post 51-L NASA and Prime Contractor FMEA/CIL. The IOA analysis approach is summarized in the following Steps 1.0 through 3.0. Step 4.0 summarizes the assessment of the NASA and Prime Contractor FMEA/CIL which is documented in this report.

Step 1.0 Subsystem Familiarization
- 1.1 Define subsystem functions
- 1.2 Define subsystem components
- 1.3 Define subsystem specific ground rules and assumptions

Step 2.0 Define subsystem analysis diagram
- 2.1 Define subsystem
- 2.2 Define major assemblies
- 2.3 Develop detailed subsystem representations

Step 3.0 Failure events definition
- 3.1 Construct matrix of failure modes
- 3.2 Document IOA analysis results

Step 4.0 Compare IOA analysis data to NASA FMEA/CIL
- 4.1 Resolve differences
- 4.2 Review in-house
- 4.3 Document assessment issues
- 4.4 Forward findings to Project Manager

2.4 Ground Rules and Assumptions

The ground rules and assumptions used in the IOA are defined in Appendix B. There were no subsystem specific ground rules and assumptions used in this analysis.

3.0 SUBSYSTEM DESCRIPTION

ORIGINAL PAGE IS OF POOR QUALITY

3.1 Design and Function

The ATVC servoactuators gimbal the main engines in pitch and yaw to provide for attitude and flight path control during ascent. There are two Ascent Thrust Vector Control (ATVC) actuators for each ME, one for pitch movement and one for yaw movement. Each actuator receives four command voltages, one from each ATVC driver electronics channel. Each actuator employs two of the three Orbiter hydraulic systems (one primary and one secondary). Each METVC servoactuator consists of the following components:

1. Switching valve. Two Orbiter hydraulic systems are connected to the valve. The output from the valve connects to four servovalves and to a power spool. The valve will shift position when the hydraulic pressure from the controlling hydraulic system is less than 1200 to 1500 psi and will furnish standby pressure to the actuator.

2. Four electro-hydraulic servovalves. Each servovalve consists of a second-stage valve, a torque motor assembly with power valve feedback wire, a mechanical position feedback spring cage assembly, a bypass valve, a dynamic pressure feedback valve, and a secondary delta pressure transducer. The function of the servovalve is to generate secondary hydraulic pressure to drive a power spool valve in response to position commands from the ATVC electronic driver.

3. Torque motor assembly. The assembly consists of dual magnets, a flapper valve and two feedback wires attached to the flapper; one wire is linked to the servovalve and the other is linked to the power spool valve. The wires are used to control the spool velocity. When a command voltage generates a torque, it causes the flapper to rotate in a clockwise or counterclockwise direction causing a pressure buildup in either the right or left sections of the servovalve, thus moving the valve to the right or left. When the valve is displaced, the hydraulic pressure is transferred to the power spool which then transfers hydraulic pressure to the primary drive piston.

4. Mechanical position feedback assembly. The assembly links each of the four torque motor flappers to the primary piston. The assembly allows the flapper to rotate initially in response to a command voltage input, and then mechanically moves the flapper back to its neutral position as the primary piston reaches its commanded position.

5. Bypass valve. The bypass valve isolates a servovalve when a secondary delta pressure is determined to be bad by the ATVC electronics. When an isolation command is issued to a solenoid a piston shuttles against a spring. This allows hydraulic pressure to shuttle a second piston which inhibits

hydraulic flow from the servovalve to the power piston. This equalizes pressure on both sides of the hydraulic supply which allows the servovalve to float, thus isolating it from the system.

6. Secondary delta pressure transducer. Each servovalve has a transducer which measures the resistance its servovalve sees relative to the other three servovalves. It sends signals to the ATVC electronics which determines which, if any, delta pressure is outside allowable limits. If a delta pressure fails, the TVC sends an isolation command to the bypass valve.

7. Power spool valve assembly. Each actuator has one power spool which provides primary hydraulic pressure to the primary piston. The power spool consists of a cylinder that contains a linear power spool. The power spool has a central position whose motion is driven by the summation of the secondary delta pressure from the four servovalves. When the power spool is displaced, hydraulic fluid is directed through a lock valve to the primary piston. The lock valve hydraulically isolates the cylinder and primary piston from the hydraulic source to prevent further movement of the primary piston. If there is a hydraulic failure, the lock valve spool moves (due to spring pressure) to a closed position which locks the primary piston in its last commanded position. A force limiter valve limits internal cylinder pressure to 4050 psi. (The valve was used during the OFT program to determine side loads during main engine gimbaling.) The valve is functionally non-critical. Instrumentation has been removed from the Orbiter.

8. Cylinder and ram/piston assembly. The assembly produces linear motion (extend or retract) to move the SSME in pitch or yaw, and mechanical position feedback cam and a feedback scissor assembly which connects to the mechanical position feedback spring cage assembly. The main cylinder reservoirs receive hydraulic pressure or return the Orbiter hydraulic supply through the feed/return lines leading to the power valve via the lock valve. As the ram moves, the scissor assembly contracts or expands, pushing the mechanical linkage (up or down) which moves the torque motor flapper. When the piston/cam reaches its commanded position, the feedback assembly removes secondary fluid pressures to the power valve.

3.2 Interfaces and Locations

The ATVC servoactuators interface with the four ATVC electronics drivers which receive commands via four MDMs from the four GPCs. Crew initiated command inputs are through the GPCs. The crew can turn power on or off to any ATVC channel and place a FCS channel in OVERRIDE which bypasses the ATVC fault detection circuitry.

Each actuator is fastened to the Orbiter thrust structures and to the powerhead of one of the three SSMEs.

Crew inputs fall into three areas, rotational hand controller (RHC) commands, override commands and ATVC power.

The FA MDMs and the ATVC electronic drives are located in Avionics Bays 4, 5 and 6.

FCS channel monitor switches are located on Panel C3. The ATVC power switches are located on Panel 017.

The two displays relative to MPS ATVC are the caution and warning (C&W) matrix (Panel F7) and the GNC System Summary 1 display. The GNC System Summary 1 display (PASS and BFS) shows a down arrow for an FCS channel that has isolated a failed servovalve and a fault message.

3.3 Hierarchy

Figure 2 is a block diagram of the ATVC servo actuators. Figures 3 through 8 show components which were analyzed for failure modes.

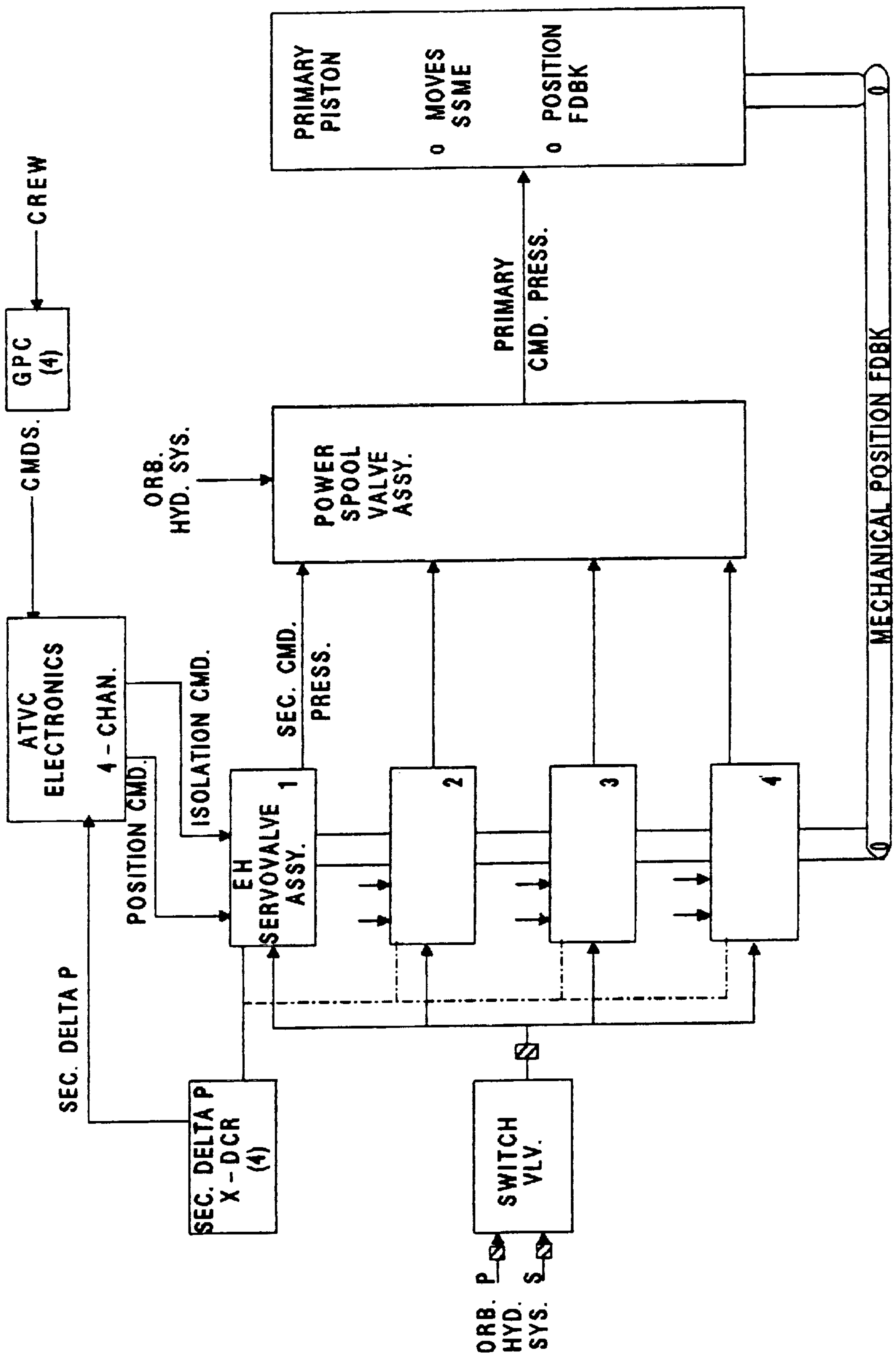


Figure 2 - ME TVC ACTUATOR BLOCK DIAGRAM

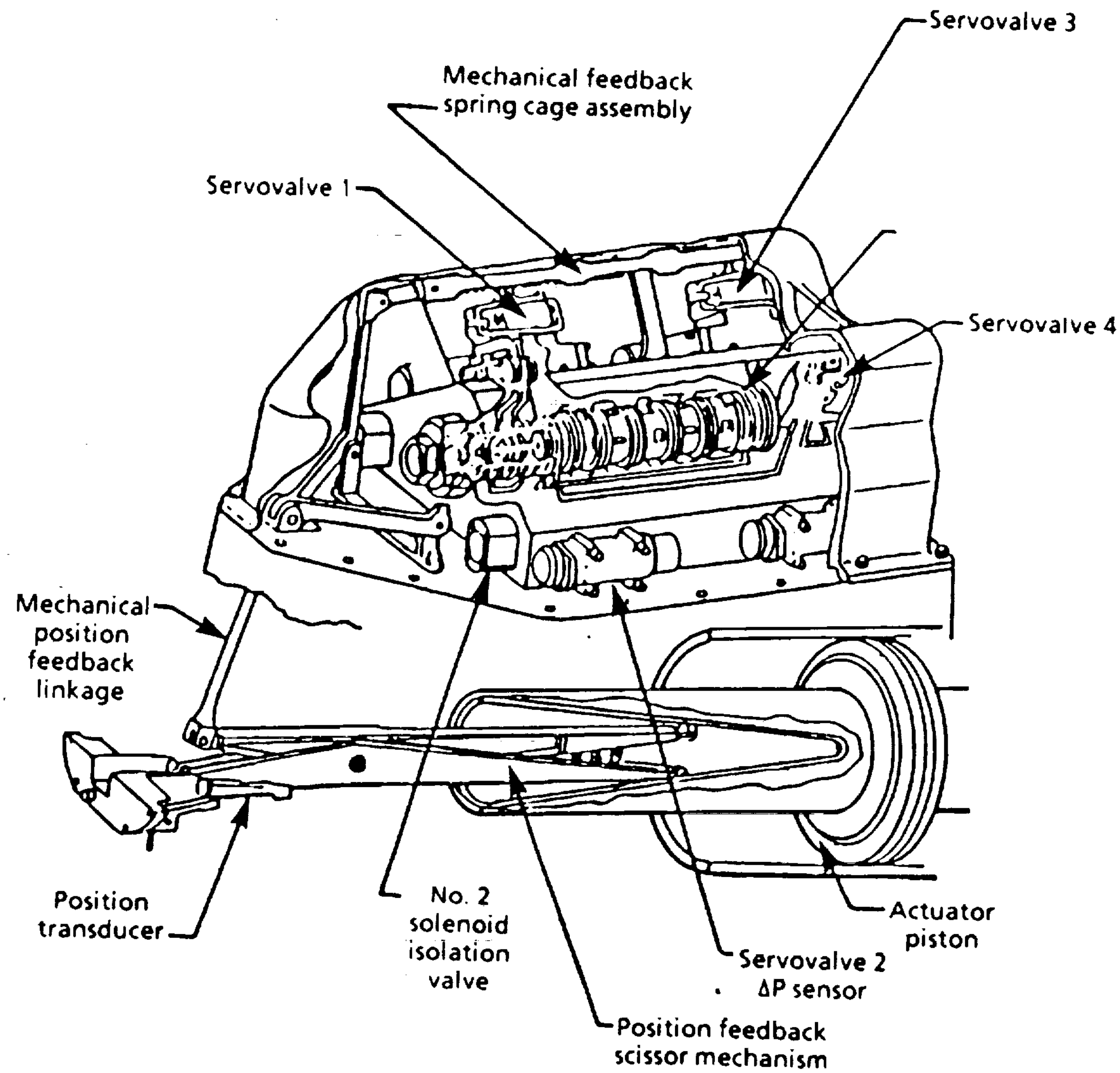


Figure 3 - TYPICAL ACTUATOR ASSEMBLY

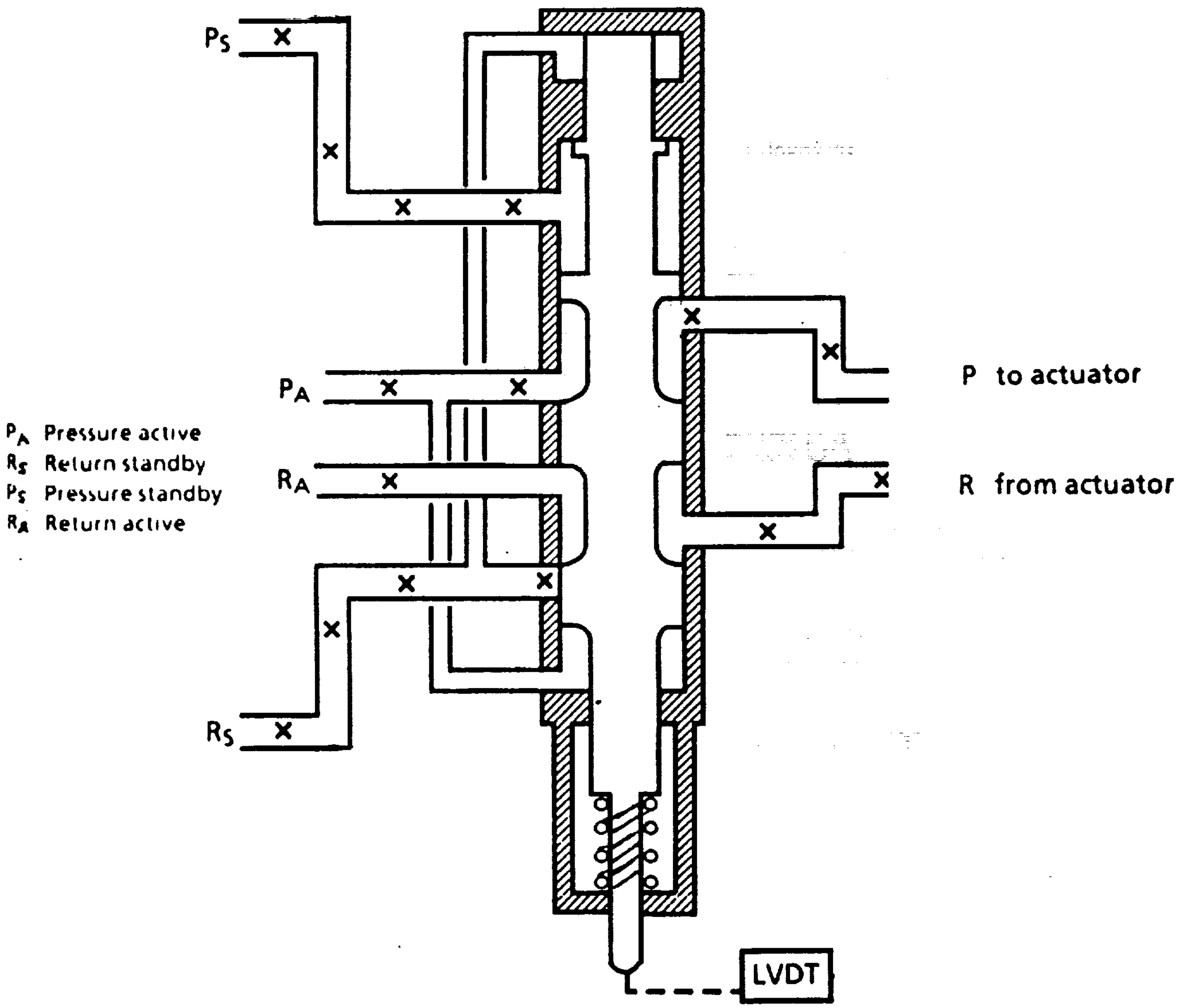


Figure 4 - SWITCHING VALVE

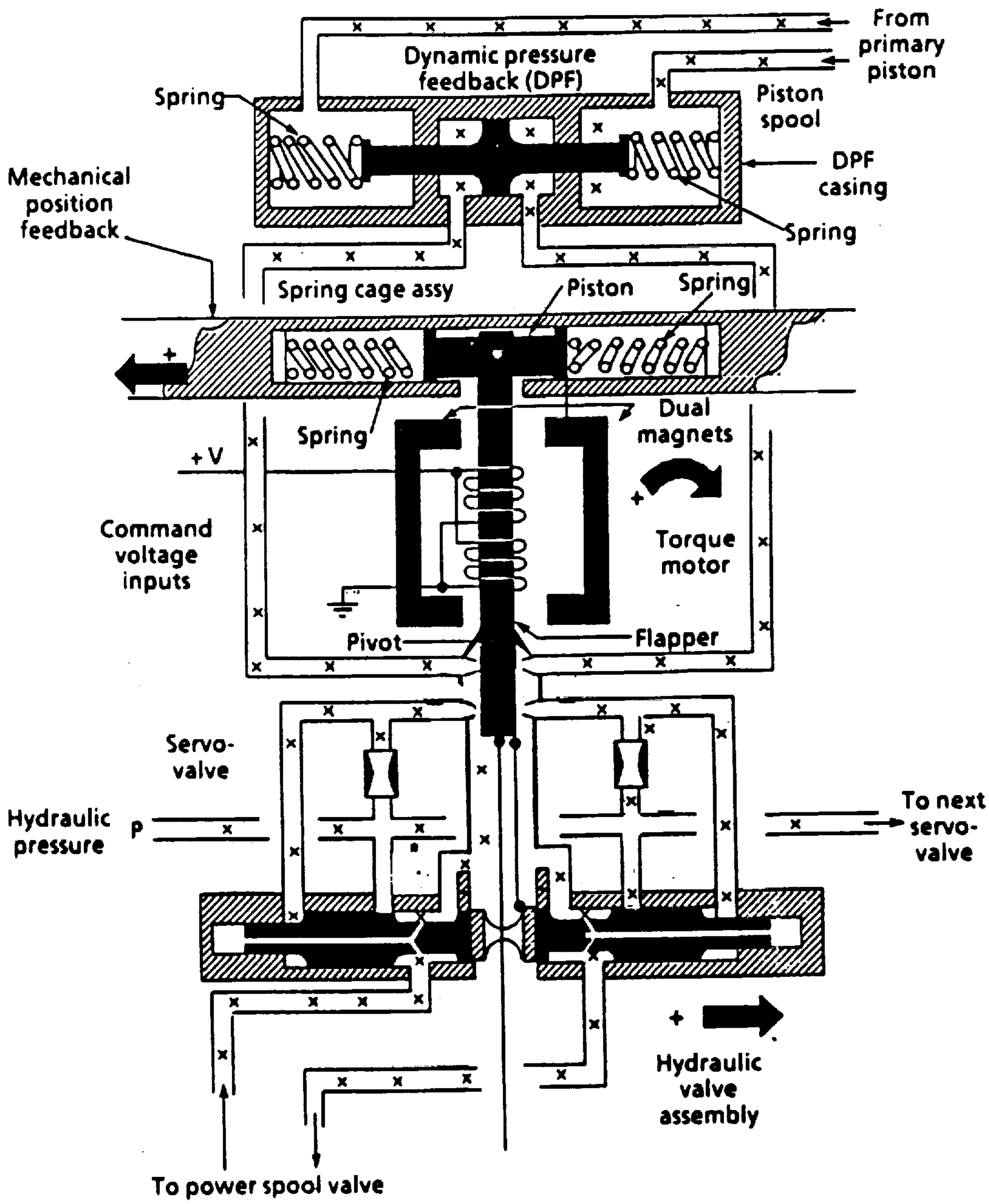


Figure 5 - E-H SERVOVALVE ASSEMBLY

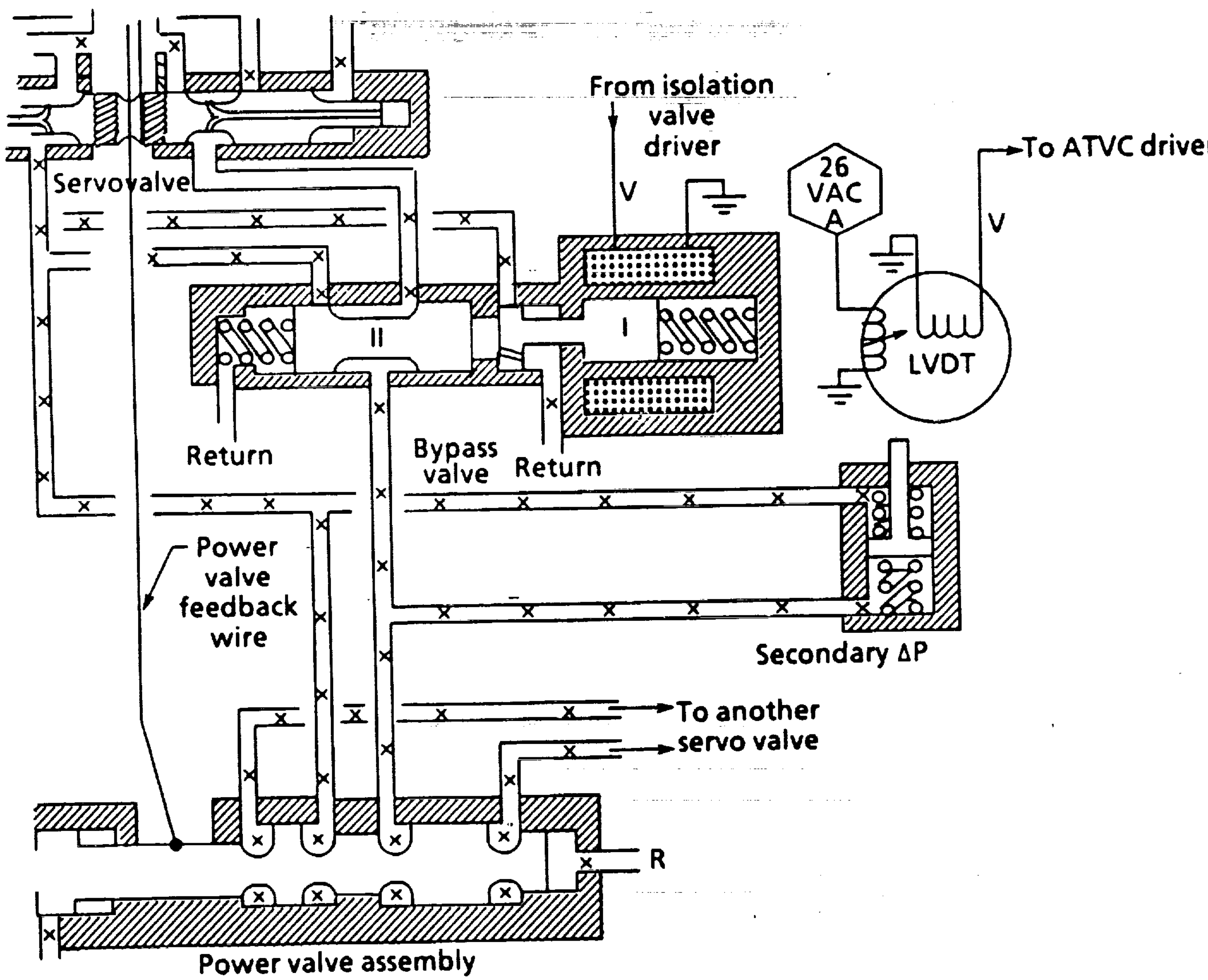


Figure 6 - BYPASS VALVE

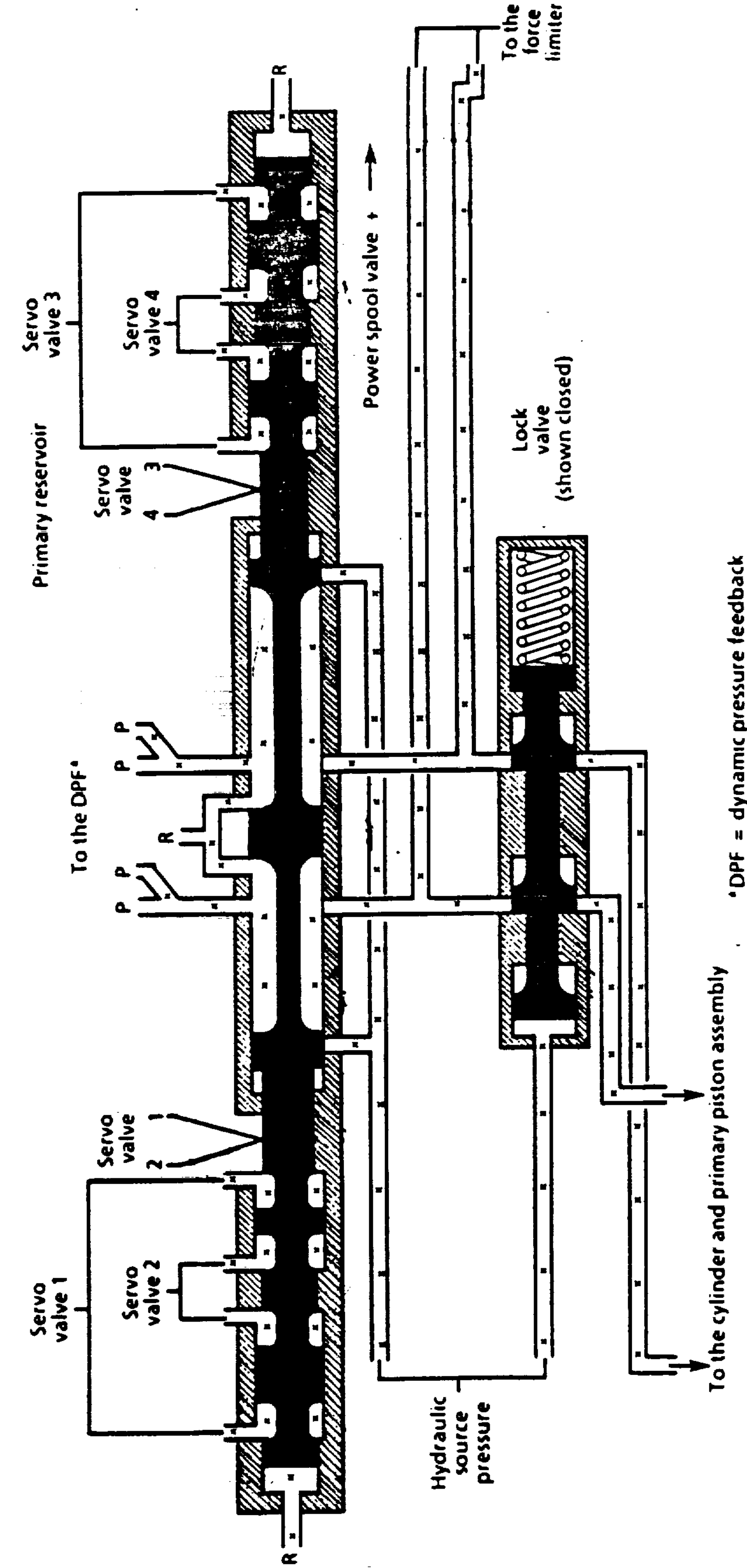


Figure 7 - POWER SPOOL VALVE ASSEMBLY

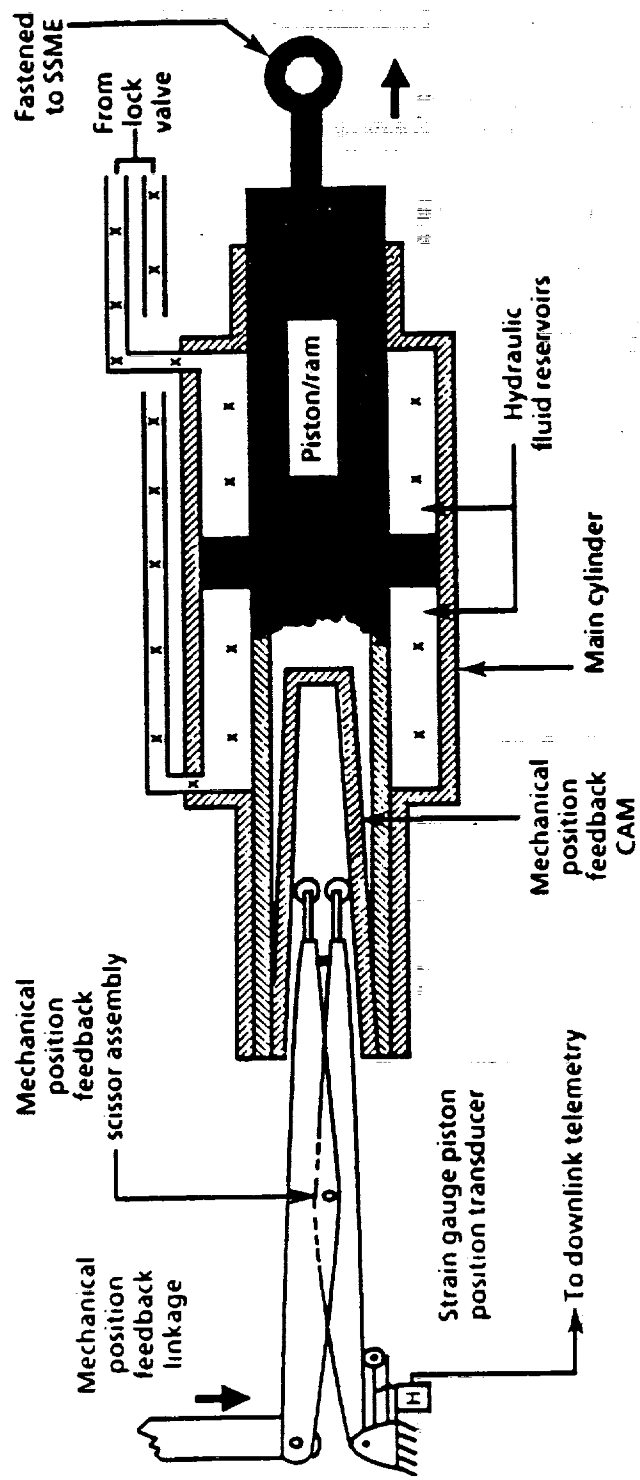


Figure 8 - CYLINDER AND PISTON/RAM ASSEMBLY

4.0 ASSESSMENT RESULTS

The IOA analysis of the ATVC actuator hardware initially generated twenty-five failure mode worksheets and identified sixteen Potential Critical Items (PCIs) before starting the assessment process. The results were compared to the proposed Post 51-L baseline (5 May 1987) of (Note 1) twenty-one FMEAs and fifteen CIL items and the updated (7 December 1987) version of (Note 1) twenty-one FMEAs and thirteen CIL items. The discrepancy between the number of IOA and NASA FMEAs can be explained by the different approach used by NASA and IOA to group modes. Upon completion of the assessment and after discussions with the NASA subsystem manager, an agreement between the NASA FMEA/CIL items and the IOA failure modes was reached.

Note 1. Have received Post 51-L CIL Items Only. Have not received all the Post 51-L NASA FMEAs as of the date of this report. Non-CIL items comparison was based on review of NASA Pre 51-L baseline and IOA analysis.

In the following, the unmapped IOA column is the raw number of IOA failure modes. The mapped IOA column is the number of IOA failuremodes after they have been mapped into the NASA FMEAs. The issues column is the IOA failure modes that were unable to be mapped into NASA FMEAs.

ATVC Actuator Elements	IOA Unmapped	IOA Mapped	NASA	Issues
Hydraulic Valve Module	20	17	17	0
Servoactuator	3	2	2	0
Primary Piston Assembly	2	2	2	0
	25	21	21	0

Appendix C presents the detailed assessment worksheets for each failure modes identified and assessment. Appendix D highlights the NASA critical items and corresponding IOA worksheet ID. Appendix E contains IOA analysis worksheets supplementing previous analysis results reported in STS Engineering and Operations Support (STSEOS) Working Paper 1.0-WP-VA86001-06, Analysis of the ATVC actuator, 3 December 1986. No supplemtal analysis worksheets were generated for the ATVC assessment. Appendix F provides a cross reference between the NASA FMEA and corresponding IOA worksheets. IOA recommendations are also summarized.

A summary of the quantity of NASA FMEAs assessed, versus the recommended IOA baseline and any issues identified is presented in Table I.

Table I Summary of IOA FMEA Assessment			
Component	NASA	IOA	Issues
o Servoactuator	2	2	0
o Hydraulic Valve Module Elements			
o Switch Valve	1	1	0
o E-H Servovalve	2	2	0
o Filter	2	2	0
o Bypass Valve	1	1	0
o Sec. Delta P X-DCER	1	1	0
o Power Spool	1	1	0
o Check Valve	2	2	0
o Lock Valve	2	2	0
o Force Limiter Valve	2	2	0
o Dynamic Press Fdble			0
Valve	1	1	0
o Flow Cutoff Valve	2	2	0
o Primary Piston Assy			
o Mech. Fdble. Assy	1	1	0
o Cylinder and Ram/ Piston	1	1	0
TOTAL	21	21	0

A summary of the quantity of NASA CIL items assessed, versus the recommended IOA baseline, and any issues identified is presented in Table II.

Table II Summary of IOA CIL Assessment			
Component	NASA	IOA	Issues
o Servoactuator	2	2	0
o Hydraulic Valve Module Elements			
o Switch Valve	1	1	0
o E-H Servovalve	1	1	0
o Filter	1	1	0
o Bypass Valve			
o Sec. Delta P X-DCER			
o Power Spool	1	1	0
o Check Valve	2	2	0
o Lock Valve	2	2	0
o Force Limiter Valve			
o Dynamic Press Fdble Valve	1	1	0
o Flow Cutoff Valve			
o Primary Piston Assy			
o Mech. Fdble. Assy	1	1	0
o Cylinder and Ram/ Piston	1	1	0
TOTAL	13	13	0

Table III presents a summary of the IOA recommended failure criticalities for the Post 51-L FMEA baseline. Further discussion of each of these subdivisions and the applicable failure modes is provided in subsequent paragraphs.

TABLE III Summary of IOA Recommended Failure Criticalities

Criticality:	1/1	2/1R	2/2	3/1R	3/2R	3/3	TOTAL
o Servoactuator	1	1					2
o Hydraulic Valve Module Elements							
o Switch Valve		1					1
o E-H Servovalve		1		1			2
o Filter	1					1	2
o Bypass Valve				1			1
o Sec. Delta P X-DCER				1			1
o Power Spool	1						1
o Check Valve	1	1					2
o Lock Valve	2						2
o Force Limiter Valve						2	2
o Dynamic Press Fdble Valve				1			1
o Flow Cutoff Valve						2	2
o Primary Piston Assy							
o Mech. Fdble. Assy	1						1
o Cylinder and Ram/ Piston	1						1
TOTAL	8	4	-	4	-	5	21

Of the failure modes analyzed, fifteen were determined to be critical items. A summary of the IOA recommended critical items is presented in Table IV.

TABLE IV Summary of IOA Recommended Failure Criticalities

Criticality:	1/1	2/1R	2/2	3/1R	3/2R	3/3	TOTAL
o Servoactuator	1	1					2
o Hydraulic Valve Module Elements							
o Switch Valve		1					1
o E-H Servovalve		1					1
o Filter	1						1
o Bypass Valve							
o Sec. Delta P X-DCER							
o Power Spool	1						1
o Check Valve	1	1					2
o Lock Valve	2						2
o Force Limiter Valve							
o Dynamic Press Fdble Valve				1			1
o Flow Cutoff Valve							
o Primary Piston Assy							
o Mech. Fdble. Assy	1						1
o Cylinder and Ram/ Piston	1						1
TOTAL	8	4	-	1	-	-	13

The scheme for assigning IOA assessment (Appendix C) and analysis (Appendix E) worksheet numbers is shown in Table V.

Table V IOA Worksheet Numbers

Component	IOA ID Number
o Servoactuator	ATVC-101 thru ATVC-103
o Hydrauliv Valve	ATVC-104 thru ATVC-120
o Primary Piston Assembly	ATVC-121 thru ATVC-125

4.1 Servoactuator

Failures which were related to the servoactuator as an entity were first analyzed. Critical failures were associated with gross loss of hydraulic fluid due to complete seal failure, and hydraulic manifold rupture. Hydraulic fluid loss was also caused by component rupture such as EH servovalves, dynamic pressure feedback valves, force limiter valves and lock valves. There were no differences between the IOA and NASA analysis.

4.2 Hydraulic Valve Module

Components of the hydraulic valve module were individually analyze. Most critical failures of these components included loss of command signal input; check, power, switch and lock valve failures due to contamination, clogged filters. One IOA failure, ruptured filter, was determined to be a non-credible failure during the assessment process. Since no known conditions could exist that would rupture the filter no FMEA was considered necessary. Two failures (open/closed) of the dynamic pressure feedback valves were identified by the IOA which had not been included in the pre-51L NASA FMEA/CIL. The function of the valves is to apply a damping force at the servovalve assembly to damp engine resonance during periods of high vibrating. The original IOA analysis considered the failures to be non-critical. There failure modes were discussed with NASA. Further analysis by RI showed that the failures were critical and could cause the actuators to become unstable resulting in possible loss of engine control. A criticality of 3/1R with FFP of screens was assigned the failures. The only other differences were minor and involved pass/fail of redundancy screen B for three criticality 2/1R items. Two IOA failures assigned a criticality of 2/1R were downgraded to 3/1R; and one other IOA failure (3/3) was upgraded to 3/1R during the assessment process.

4.3 Primary Piston Assembly

Critical failures associated with the primary ram/piston assembly were due to mechanical failures, fractures and jammed components. These failures module jamming or separation of the mechanical position feedback spring cage assembly, loss of the piston rod gland retention in the main body, and fracture of the tail stock (thrust structure), piston rod end (engine), piston head and piston rod. There were no differences between the IOA and NASA analysis.

4.4 Failure Comparison

The main reason for IOA intially having more CIL items than NASA was that NASA combined failure of components which had the same effect, whereas the IOA wrote failure sheets for each item. Review of the NASA CIL items showed that all of the IOA failures had been analyzed. Since the combined failures all resulted in the same effect it was concluded that there were no issues with IOA. Minor differences such as pass or fail of screens were readily resolved. Frequent discussions with the subsystem manager resulted in a better understanding of the system and component operation. As a result of these discussions several IOA criticalities were downgraded. In addition, an additional failure mode not included in the Pre 51-L NASA FMEAs was added to the Post 51-L baseline.

5.0 REFERENCES

Reference documentation available from NASA and Rockwell was used in the analysis. The documentation used included the following:

1. Thrust Vector Control Training Manual, MPS TV 2102, 10/19/85
2. Space Shuttle Systems Handbook, JSC 11174, 09/13/86
3. SD72-SH-0102 Definition Manual Mechanical System Hydraulics, 10/28/75
4. RI Integrated Schematics (V570-580998, -58099)
5. Shuttle MML
6. FDF (Ascent)
7. OMRSD U58AGO, V79ATO, V58A00
8. GN&C Console Handbook JSC12843
9. Discussions with S/S Manager
10. Sketches, Drawings, Etc. Reviewed with S/S Manager
11. Instructions for Preparation of FMEA and CIL, NSTS 22206, 10 October 1986

APPENDIX A
ACRONYMS

ATVC	-	Ascent Thrust Vector Control
BFS	-	Backup Flight System
C&W	-	Caution and Warning
CIL	-	Critical Items List
CRT	-	Cathode Ray Tube
delta P	-	Differential Pressure
E-H Servo VLV	-	Electro-Hydraulic Servovalve
F	-	Functional
FCS	-	Flight Control System
FMEA	-	Failure Modes Effect Analysis
GNC	-	Guidance Navigation and Control
GPC	-	General Purpose Computer
HW	-	Hardware
IOA	-	Independent Orbiter Assessment
MDAC	-	McDonnell Douglas Astronautics Company
MDM	-	Multiplexer/Demultiplexer
METVC	-	Main Engine Thrust Vector Control
ORIDE	-	Override
PASS	-	Primary Avionics Software System
RI	-	Rockwell International
RHC	-	Rotational Hand Controller
SSME	-	Space Shuttle Main Engine
SRB	-	Solid Rocket Booster

APPENDIX B

DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

APPENDIX B
DEFINITIONS, GROUND RULES, AND ASSUMPTIONS

B.1 Definitions

Definitions contained in NSTS 22206, Instructions For Preparation of FMEA/CIL, 10 October 1986, were used with the following amplifications and additions.

INTACT ABORT DEFINITIONS:

RTLS - begins at transition to OPS 6 and ends at transition to OPS 9, post-flight

TAL - begins at declaration of the abort and ends at transition to OPS 9, post-flight

AOA - begins at declaration of the abort and ends at transition to OPS 9, post-flight

ATO - begins at declaration of the abort and ends at transition to OPS 9, post-flight

CREDIBLE (CAUSE) - an event that can be predicted or expected in anticipated operational environmental conditions. Excludes an event where multiple failures must first occur to result in environmental extremes

CONTINGENCY CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

EARLY MISSION TERMINATION - termination of onorbit phase prior to planned end of mission

EFFECTS/RATIONALE - description of the case which generated the highest criticality

HIGHEST CRITICALITY - the highest functional criticality determined in the phase-by-phase analysis

MAJOR MODE (MM) - major sub-mode of software operational sequence (OPS)

MC - Memory Configuration of Primary Avionics Software System (PASS)

MISSION - assigned performance of a specific Orbiter flight with payload/objective accomplishments including orbit phasing and altitude (excludes secondary payloads such as GAS cans, middeck P/L, etc.)

MULTIPLE ORDER FAILURE - describes the failure due to a single cause or event of all units which perform a necessary (critical) function

OFF-NOMINAL CREW PROCEDURES - procedures that are utilized beyond the standard malfunction procedures, pocket checklists, and cue cards

OPS - software operational sequence

PRIMARY MISSION OBJECTIVES - worst case primary mission objectives are equal to mission objectives

PHASE DEFINITIONS:

PRELAUNCH PHASE - begins at launch count-down Orbiter power-up and ends at moding to OPS Major Mode 102 (liftoff)

LIFTOFF MISSION PHASE - begins at SRB ignition (MM 102) and ends at transition out of OPS 1 (Synonymous with ASCENT)

ONORBIT PHASE - begins at transition to OPS 2 or OPS 8 and ends at transition out of OPS 2 or OPS 8

DEORBIT PHASE - begins at transition to OPS Major Mode 301 and ends at first main landing gear touchdown

LANDING/SAFING PHASE - begins at first main gear touchdown and ends with the completion of post-landing safing operations

B.2 IOA Project Level Ground Rules and Assumptions

The philosophy embodied in NSTS 22206, Instructions for Preparation of FMEA/CIL, 10 October 1986, was employed with the following amplifications and additions.

1. The operational flight software is an accurate implementation of the Flight System Software Requirements (FSSRs).

   RATIONALE: Software verification is out-of-scope of this task.

2. After liftoff, any parameter which is monitored by system management (SM) or which drives any part of the Caution and Warning System (C&W) will support passage of Redundancy Screen B for its corresponding hardware item.

   RATIONALE: Analysis of on-board parameter availability and/or the actual monitoring by the crew is beyond the scope of this task.

3. Any data employed with flight software is assumed to be functional for the specific vehicle and specific mission being flown.

   RATIONALE: Mission data verification is out-of-scope of this task.

4. All hardware (including firmware) is manufactured and assembled to the design specifications/drawings.

   RATIONALE: Acceptance and verification testing is designed to detect and identify problems before the item is approved for use.

5. All Flight Data File crew procedures will be assumed performed as written, and will not include human error in their performance.

   RATIONALE: Failures caused by human operational error are out-of-scope of this task.

6. All hardware analyses will, as a minimum, be performed at the level of analysis existent within NASA/Prime Contractor Orbiter FMEA/CILs, and will be permitted to go to greater hardware detail levels but not lesser.

   RATIONALE: Comparison of IOA analysis results with other analyses requires that both analyses be performed to a comparable level of detail.

7. Verification that a telemetry parameter is actually monitored during AOS by ground-based personnel is not required.

   RATIONALE: Analysis of mission-dependent telemetry availability and/or the actual monitoring of applicable data by ground-based personnel is beyond the scope of this task.

8. The determination of criticalities per phase is based on the worst case effect of a failure for the phase being analyzed. The failure can occur in the phase being analyzed or in any previous phase, whichever produces the worst case effects for the phase of interest.

   RATIONALE: Assigning phase criticalities ensures a thorough and complete analysis.

9. Analysis of wire harnesses, cables, and electrical connectors to determine if FMEAs are warranted will not be performed nor FMEAs assessed.

   RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

10. Analysis of welds or brazed joints that cannot be inspected will not be performed nor FMEAs assessed.

   RATIONALE: Analysis was substantially complete prior to NSTS 22206 ground rule redirection.

11. Emergency system or hardware will include burst discs and will exclude the EMU Secondary Oxygen Pack (SOP), pressure relief valves and the landing gear pyrotechnics.

   RATIONALE: Clarify definition of emergency systems to ensure consistency throughout IOA project.

B.3 ATVC Actuator - Specific Ground Rules and Assumptions

The IOA analysis was performed to the component or assembly level of the ATVC actuator. The analysis considered the worst case effects of the hardware or functional failure on the subsystem, mission and crew and vehicle safety.

APPENDIX C
DETAILED ASSESSMENT

This section contains the IOA assessment worksheets generated during the Assessment of the Ascent Thrust Vector Control Actuator Subsystem. The information on these worksheets facilitates the comparison of the NASA FMEA/CIL (Pre and Post 51-L) to the IOA detailed analysis worksheets included in Appendix E. Each of these worksheets identifies the NASA FMEA being assessed, corresponding MDAC Analysis Worksheet ID (Appendix E), hardware item, criticality, redundancy screens, and recommendations. For each failure mode, the highest assessed hardware and functional criticality is compared and discrepancies noted as "N" in the compare row under the column where the discrepancy occurred.

LEGEND FOR IOA ASSESSMENT WORKSHEETS

Hardware Criticalities:
- 1 = Loss of life or vehicle
- 2 = Loss of mission or next failure of any redundant item (like or unlike) could cause loss of life/vehicle
- 3 = All others

Functional Criticalities:
- 1R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of life or vehicle
- 2R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of mission

Redundancy Screens A, B and C:
- P = Passed Screen
- F = Failed Screen
- NA = Not Applicable

NASA Data :
- Baseline = NASA FMEA/CIL
- New = Baseline with Proposed Post 51-L Changes

CIL Item :
- X = Included in CIL

Compare Row :
- N = Non compare for that column (deviation)

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-101
NASA FMEA #: 02-6-A01-1

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 101
ITEM: METVC SERVO ACTUATOR (6)

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
THE NASA FMEA COVERS FAILURES WHICH WERE WRITTEN AS SEPARATE FAILURES BY IOA; ATVC-101 AND ATVC-102. NO DISAGREEMENT WITH COMBINING FAILURES UNDER ONE FMEA.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-102
NASA FMEA #: 02-6-A01-1

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 102
ITEM: METVC SERVO ACTUATOR (6)

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
THE NASA FMEA COVER FAILURES WHICH WERE WRITTEN AS SEPARATE FAILURES BY IOA; ATVC-101 AND ATVC-102. NO DISAGREEMENT WITH COMBINING BOTH FAILURES UNDER ONE FMEA.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-103
NASA FMEA #: 02-6-A01-13

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 103
ITEM: METVC SERVO ACTUATOR (6)

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM	
NASA	[2 /1R]	[F]	[F]	[P]	[X]	*
IOA	[2 /1R]	[F]	[P]	[P]	[X]	
COMPARE	[/]	[ ]	[N]	[ ]	[ ]	

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA CRITICALITY. NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-104
NASA FMEA #: 02-6-A01-SW-4

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 104
ITEM: SWITCH VALVE (6)

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[F]	[P]	[X] *
IOA	[2 /1R]	[P]	[P]	[P]	[X]
COMPARE	[/]	[ ]	[N]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
AGREE THAT FAILURE FAILS REDUNDANCY SCREEN B.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-105
NASA FMEA #: 02-6-A01-5

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 105
ITEM: EH SERVOVALVE ASSY

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[X] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[N /]	[ ]	[N]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH RI/NASA THAT A HARDOVER FAILURE OF THE SERVOVALVE IS DETECTABLE AND CAN BE ISOLATED, LEAVING THREE GOOD SERVOVALVES. NASA INCLUDED THIS FAILURE AMONG OTHER FAILURES HAVING THE SAME EFFECT IN FMEA 02-6-A01-5. THERE IS NO DISAGREEMENT WITH INCLUDING THE FAILURES IN THE SAME FMEA. FAILURES ARE COVERED BY MDAC ID 105, 109 AND 110.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-106
NASA FMEA #: 02-6-A01-SV-19

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 106
ITEM: EH SERVOVALVE ASSY

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[P]	[F]	[P]	[X] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
IF THE FAILURE OCCURS WHEN COMMANDING AT OR NEAR THE NULL POSITION, THE FAULT DETECTION CIRCUITRY CANNOT DETECT THE FAILURE. THIS FAILURE WOULD GO UNDETECTED AND THE NEXT FAILURE WOULD LEAVE TWO OPERATING CHANNELS. THE HARDWARE IS 3/1R; HOWEVER, THE FAULT DETECTION CIRCUITRY CANNOT DETECT WHICH OF THE 2 CHANNELS IS GOOD IF ONE SHOULD FAIL. THIS COULD RESULT IN A POSSIBLE FORCE FLIGHT BETWEEN THE TWO CHANNELS WITH A RESULTING LOSS OF CONTROL.

NO CRITICALITY ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-107
NASA FMEA #: 02-6-A01-FE-3

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 107
ITEM: FILTER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-108
NASA FMEA #: NONE

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 108
ITEM: FILTER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[/]	[ ]	[ ]	[ ]	[ ] *
IOA	[3 /3]	[P]	[F]	[P]	[ ]
COMPARE	[N /N]	[N]	[N]	[N]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
AGREE WITH NASA. THIS IS A NON-CREDIBLE FAILURE SINCE NO KNOWN CONDITIONS COULD EXIST WHICH WOULD RUPTURE THE FILTER. NASA CIL PRE-BOARD ACTIVE - DELETE AS BEING A NON-CREDIBLE FAILURE.

NO ISSUE. INITIAL ANALYSIS WAS IN ERROR SHOWING PASS OR FAIL OF SCREENS. FAIL OR PASS OF SCREENS SHOULD BE NOT APPLICABLE.

ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-109
NASA FMEA #: 02-06-A01-5

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 109
ITEM: TORQUE MOTOR ASSY

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[N /]	[ ]	[N]	[ ]	[N]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

NASA INCLUDED THIS FAILURE AMONG OTHER FAILURES WHICH HAVE THE SAME EFFECT IN ONE FMEA. THERE IS NO DISAGREEMENT WITH INCLUDING THE FAILURE IN THE SAME FMEA. FAILURES ARE COVERED BY MDAC ID 105, 109 AND 110.

NO ISSUE. CONCUR WITH RI/NASA THAT THIS FAILURE OF THE SERVOVALVE MOTOR IS THE SAME AS HARDOVER FAILURE (MDAC ID 105) WHICH IS DETECTABLE, CAN BE ISOLATED AND LEAVES THREE GOOD CHANNELS.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-110
NASA FMEA #: 02-06-A01-5

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 110
ITEM: TORQUE MOTOR ASSY

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[N /]	[ ]	[N]	[ ]	[N]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

NASA INCLUDED THIS FAILURE AMONG OTHER FAILURES WHICH HAVE THE SAME EFFECT IN FMEA 02-06-A01-5. THERE IS NO DISAGREEMENT WITH INCLUDING THE FAILURE IN THE SAME FMEA. FAILURES ARE COVERED MDAC ID 105, 109, AND 110.

NO ISSUE. CONCUR WITH RI/NASA THAT THIS FAILURE OF THE SERVOVALVE MOTOR FLAPPER IS THE SAME AS HARDOVER FAILURE (MDAC ID 105) WHICH IS DETECTABLE, CAN BE ISOLATED AND LEAVES THREE GOOD CHANNELS.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-111
NASA FMEA #: 02-6-A01-FB-14

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 111
ITEM: MECHANICAL POSITION FEEDBACK SPRING CAGE ASSY

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-112
NASA FMEA #: 02-6-A01-11

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 112
ITEM: BYPASS VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[3 /1R]	[P]	[P]	[P]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
NO ISSUE.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-113
NASA FMEA #: 02-6-A01-12

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 113
ITEM: SECONDARY DELTA-P TRANSDUCER

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[P]	[P]	[P]	[ ] *
IOA	[2 /1R]	[P]	[F]	[P]	[X]
COMPARE	[N /]	[ ]	[N]	[ ]	[N]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:
NO CRITICALITY ISSUE. AGREE WITH NASA ASSESSMENT, FAILURE OF ONE TRANSDUCER IS DETECTABLE AND LEAVES THREE GOOD TRANSDUCERS FOR REMAINING SERVO CHANNELS.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-114
NASA FMEA #: 02-6-A01-PS-2

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 114
ITEM: POWER SPOOL VALVE ASSY

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-115
NASA FMEA #: 02-06-A01-CV-16

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 115
ITEM: CHECK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE:	12/07/86	NASA DATA:	
ASSESSMENT ID:	ATVC-116	BASELINE	[ ]
NASA FMEA #:	02-6-A01-CV-17	NEW	[X]

SUBSYSTEM: ATVC
MDAC ID: 116
ITEM: CHECK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[2 /1R]	[F]	[F]	[P]	[X] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[N /N]	[N]	[N]	[N]	[N]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
CONCUR WITH NASA CRITICALITY. THE ORIGINAL IOA ANALYSIS CONSIDERED THAT IN THE EVENT OF LOSS OF HYDRAULIC PRESSURE AND THE CHECK VALVE FAILS OPEN THAT THE ACTUATOR LOCK VALVE ALSO HAD TO FAIL OPEN TO CAUSE A PROBLEM. HOWEVER, DISCUSSIONS WITH SUBSYSTEM MANAGER INDICATES THAT WITH HIGH HINGE MOMENTS THE BACK PRESSURE EXERTED ON THE LOCK VALVE WILL PREVENT LOCK VALVE FROM FUNCTIONING AND THE ENGINE CAN GO HARDOVER THEN THE LOCK VALVE WILL FUNCTION AND LOCK THE ENGINE AT THIS FUNCTION.

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-117
NASA FMEA #: 02-6-A01-LV-9

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 117
ITEM: LOCK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-118
NASA FMEA #: 02-6-A01-LV-10

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 118
ITEM: LOCK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-119
NASA FMEA #: 02-6-A01-7

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 119
ITEM: FORCE LIMITER VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-120
NASA FMEA #: 02-6-A01-8

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ATVC
MDAC ID: 120
ITEM: FORCE LIMITER VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-121
NASA FMEA #: 02-6-A01-6

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 121
ITEM: CYLINDER AND RAM/PISTON ASS'Y

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[1 /1]	[NA]	[NA]	[NA]	[X] *
IOA	[1 /1]	[NA]	[NA]	[NA]	[X]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

	[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-122
NASA FMEA #: 02-06-A01-FA-23

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 122
ITEM: DYNAMIC PRESSURE FEEDBACK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[F]	[F]	[P]	[X] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/N]	[N]	[N]	[N]	[N]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
THIS FAILURE WAS NOT INCLUDED IN THE NASA PRE 51-L BASELINE. FOR THE POST 51-L UPDATE NASA/RI AGREED TO THIS FAILURE BUT HAVE MADE IT A 3/1R CRIT, AND A CIL ITEM BASED ON FAILURE OF SCREENS A AND B. BASED ON DISCUSSIONS WITH NASA, IOA CONCURS WITH THE NEW FMEA/CIL. THERE IS FURTHER AGREEMENT THAT ONE FMEA/CIL COVERS BOTH ATVC-122 AND ATVC-123 FAILURES. IOA CONCURS WITH NASA/RI. (LOSS OF THREE OF THE FOUR VALVES COULD RESULT IN AN UNSTABLE ATUATOR UNDER CERTAIN VIBRATION CONDITIONS WHICH COULD RESULT IN LOSS OF VEHICLE CONTROL.)

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-123
NASA FMEA #: 02-06-A01-FA-23

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 123
ITEM: DYNAMIC PRESSURE FEEDBACK VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /1R]	[F]	[F]	[P]	[X] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/N]	[N]	[N]	[N]	[N]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)
ADEQUATE [X]
INADEQUATE [ ]

REMARKS:
THIS FAILURE WAS NOT INCLUDED IN THE NASA PRE 51-L BASELINE. FOR THE POST 51-L UPDATE NASA/RI AGREED TO THIS FAILURE BUT HAVE MADE IT A 3/1R CRIT, AND A CIL ITEM BASED ON FAILURE OF SCREEN A AND B. BASED ON DISCUSSIONS WITH NASA, IOA CONCURS WITH THE NEW FMEA/CIL. THERE IS FURTHER AGREEMENT THAT ONE FMEA/CIL WILL COVER BOTH ATVC-123 AND ATVC-122 FAILURES. IOA CONCURS WITH NASA/RI. (LOSS OF THREE VALVES COVERED RESULT IN AN UNSTABLE ACTUATOR UNDER CERTAIN VIBRATION CONDITIONS WHICH COULD RESULT IN LOSS OF VEHICLE CONTROL).

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-124
NASA FMEA #: 02-6-A01-21

NASA DATA:
BASELINE [ ]
NEW [X]

SUBSYSTEM: ATVC
MDAC ID: 124
ITEM: FLOW CUTOFF VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX C
ASSESSMENT WORKSHEET

ASSESSMENT DATE: 12/07/86
ASSESSMENT ID: ATVC-125
NASA FMEA #: 02-6-A01-22

NASA DATA:
BASELINE [X]
NEW [ ]

SUBSYSTEM: ATVC
MDAC ID: 125
ITEM: FLOW CUTOFF VALVE

LEAD ANALYST: R. WILSON

ASSESSMENT:

	CRITICALITY FLIGHT HDW/FUNC	REDUNDANCY SCREENS A	B	C	CIL ITEM
NASA	[3 /3]	[NA]	[NA]	[NA]	[ ] *
IOA	[3 /3]	[NA]	[NA]	[NA]	[ ]
COMPARE	[/]	[ ]	[ ]	[ ]	[ ]

RECOMMENDATIONS: (If different from NASA)

[/]	[ ]	[ ]	[ ]	[ ] (ADD/DELETE)

* CIL RETENTION RATIONALE: (If applicable)

ADEQUATE [ ]
INADEQUATE [ ]

REMARKS:

APPENDIX D
CRITICAL ITEMS

NASA FMEA	MDAC ID	ITEM	FAILURE MODE
02-6-A01-1	101	SERVOACTUATOR	EXTERNAL LEAKAGE, COMPONENT
02-6-A01-1	102	SERVOACTUATOR	RUPTURE DOWNSTREAM OF SWITCHING VALVE
02-6-A01-13	103	SERVOACTUATOR	LEAKAGE, ELASTOMERIC SEAL FAILURE
02-6-A01-SW-4	104	SWITCH VALVE	FAIL TO TRANSFER
02-6-A01-SV-19	106	E-H SERVOVALVE	FAIL TO TRANSFER
02-6-A01-FE-3	107	FILTER	CLOGGED
02-6-A01-FB-4	111	MECHANICAL POSITION FEEDBACK ASSEMBLY	JAMMED OR SEPARATED
02-6-A01-PS-2	114	POWER SPOOL	JAMMED
02-6-A01-CV-16	115	CHECK VALVE	FAIL CLOSED
02-6-A01-CV-17	116	CHECK VALVE	FAIL OPEN
02-6-A01-LV-19	117	LOCK VALVE	FAIL CLOSED
02-6-A01-LV-10	118	LOCK VALVE	FAIL OPEN
02-6-A01-6	121	CYLINDER AND RAM/ PISTON ASSEMBLY	FRACTURE
02-6-A01-FA-23	122	DYNAMIC PRESSURE	FAIL OPEN/CLOSED
02-6-A01-FA-23	123	FEEDBACK VALVE	FAIL TO RETURN TO NULL

APPENDIX E
DETAILED ANALYSIS

This appendix contains the IOA analysis worksheets supplementing previous results reported in STSEOS Working Paper 1.0-WP-VA86001-06, Analysis of the ATVC Actuators, (3 December 1986). Prior results were obtained independently and documented before starting the FMEA/CIL assessment activity. Supplemental analysis was performed to address failure modes not previously considered by the IOA. Each sheet identifies the hardware item being analyzed, parent assembly and function performed. For each failure mode possible causes are identified, and hardware and functional criticality for each mission phase are determined as described in NSTS 22206, Instructions for Preparation of FMEA and CIL, 10 October 1986. Failure mode effects are described at the bottom of each sheet and worst case criticality is identified at the top. There were no supplemental analysis worksheets generated for the ATVC Actuators.

LEGEND FOR IOA ANALYSIS WORKSHEETS

Hardware Criticalities:
- 1 = Loss of life or vehicle
- 2 = Loss of mission or next failure of any redundant item (like or unlike) could cause loss of life/vehicle
- 3 = All others

Functional Criticalities:
- 1R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of life or vehicle.
- 2R = Redundant hardware items (like or unlike) all of which, if failed, could cause loss of mission.

Redundancy Screen A:
- 1 = Is Checked Out PreFlight
- 2 = Is Capable of Check Out PreFlight
- 3 = Not Capable of Check Out PreFlight
- NA = Not Applicable

Redundancy Screens B and C:
- P = Passed Screen
- F = Failed Screen
- NA = Not Applicable

APPENDIX F

NASA FMEA TO IOA WORKSHEET CROSS REFERENCE

This section provides a cross reference between the NASA FMEA and corresponding IOA analysis worksheet(s) included in Appendix E. The Appendix F comparison identifies the NASA FMEA Number, IOA Assessment Number, criticality and redundancy screen data, and IOA recommendations.

Appendix F Legend.

<u>Code Definition</u>

All initial IOA criticality and redundancy screen differences were resolved with the NASA subsystem manager. In addition, the combining of like failures under one FMEA were agreed to.

APPENDIX F

NASA FMEA TO IOA WORKSHEET CROSS REFERENCE / RECOMMENDATIONS

IDENTIFIERS		NASA				IOA RECOMMENDATIONS *						
NASA FMEA NUMBER	IOA ASSESSMENT NO.	CRIT HW/F	SCREENS A	B	C	CRIT HW/F	SCREENS A	B	C	OTHER (SEE LEGEND CODE)	ISSUE
02-06-A01-5	ATVC-109	3/1R	P	P	P	/					
02-06-A01-5	ATVC-110	3/1R	P	P	P	/					
02-06-A01-CV-16	ATVC-115	1/1	NA	NA	NA	/					
02-06-A01-FA-23	ATVC-122	3/1R	F	F	P	/					
02-6-A01-1	ATVC-101	1/1	NA	NA	NA	/					
02-6-A01-1	ATVC-102	1/1	NA	NA	NA	/					
02-6-A01-11	ATVC-112	3/1R	P	P	P	/					
02-6-A01-12	ATVC-113	3/1R	P	P	P	/					
02-6-A01-13	ATVC-103	2/1R	F	F	P	/					
02-6-A01-21	ATVC-124	3/3	NA	NA	NA	/					
02-6-A01-22	ATVC-125	3/3	NA	NA	NA	/					
02-6-A01-5	ATVC-105	3/1R	P	P	P	/					
02-6-A01-6	ATVC-121	1/1	NA	NA	NA	/					
02-6-A01-7	ATVC-119	3/3	NA	NA	NA	/					
02-6-A01-8	ATVC-120	3/3	NA	NA	NA	/					
02-6-A01-CV-17	ATVC-116	2/1R	F	F	P	/					
02-6-A01-FA-23	ATVC-123	3/1R	F	F	P	/					
02-6-A01-FB-14	ATVC-111	1/1	NA	NA	NA	/					
02-6-A01-FE-3	ATVC-107	1/1	NA	NA	NA	/					
02-6-A01-LV-10	ATVC-118	1/1	NA	NA	NA	/					
02-6-A01-LV-9	ATVC-117	1/1	NA	NA	NA	/					
02-6-A01-PS-2	ATVC-114	1/1	NA	NA	NA	/					
02-6-A01-SV-19	ATVC-106	2/1R	P	F	P	/					
02-6-A01-SW-4	ATVC-104	2/1R	P	F	P	/					
NONE	ATVC-108	/				/					